

JCAT

Alternative Coatings for Fasteners on USMC- Expeditionary Fighting Vehicle

January 26, 2006

Hilton San Diego Resort
1775 East Mission Bay Drive
San Diego, CA 92109

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 26 JAN 2006		2. REPORT TYPE		3. DATES COVERED 00-00-2006 to 00-00-2006	
4. TITLE AND SUBTITLE Alternative Coatings for Fasteners on USMC USMC-Expeditionary Fighting Vehicle				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Sabre Systems, Inc.,Naval Air Systems Command,48066 Shaw Road, Bldg 2188,Patuxent River,MD,20670				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES 26th Replacement of Hard Chrome and Cadmium Plating Program Review Meeting, January 24-26, 2006, San Diego, CA. Sponsored by SERDP/ESTCP.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 53	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Presented by:

Amy Hilgeman (Sabre Systems, Inc.)

Chemist

NAVAIR

48066 Shaw Road, Bldg 2188

Patuxent River, MD 20670-1906

301-342-0986

amy.leis.ctr@navy.mil

Contributors:

Bill Nickerson (NAVAIR)

48066 Shaw Road, Bldg. 2188
Patuxent River, MD 20670-1906
301-342-8864
william.nickerson@navy.mil

Kevin Clark (GDLS)

14041 Worth Avenue
Woodbridge, VA 22192
703-490-7533
clarkk@gdls.com

Subra Bettadapur (DRPM-AAA, USMC)

14041 Worth Avenue
Woodbridge, VA 22192
703-492-3360
BettadapurSS@EFV.USMC.MIL

USMC-EFV

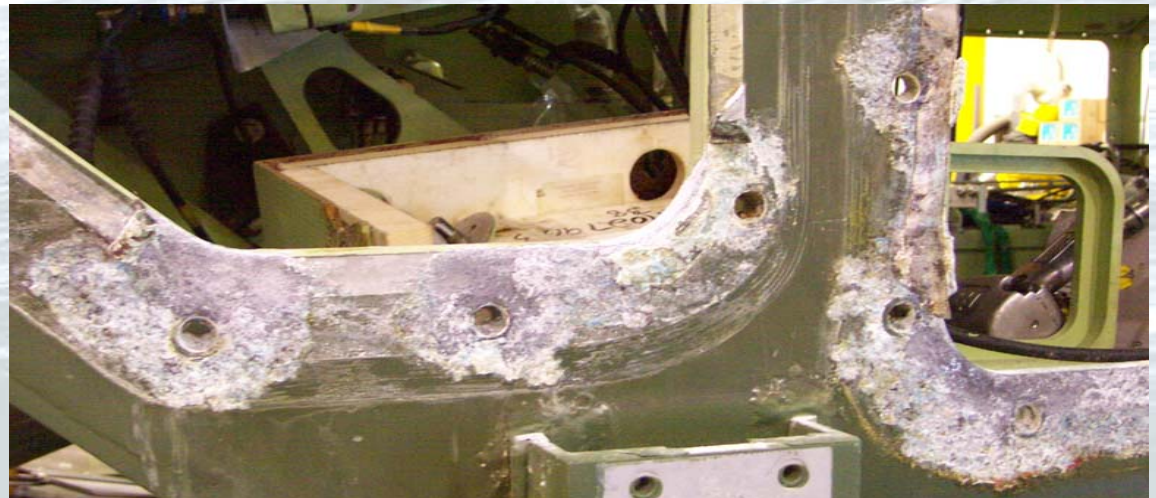
- Self-deploying, high-water-speed, armored amphibious vehicle.
- Operated by a crew of 3 Marines.
- Transports up to 17 combat equipped Marines from Naval ships beyond the visual horizon to inland objectives.

<http://www.efv.usmc.mil/>



Purpose

- Environmentally “green” program – no hexavalent chrome, no cadmium, etc.
- Original set-up – all bare fasteners contributing to severe galvanic corrosion.
- Preliminary screening of alternative fastener coatings.



Coatings

- **S4340**
 - **Cadmium** – ASTM F519, Table II, Treatment B, chromate seal, 0.5 mil (NAVAIR)
 - **Zinc Nickel** – AMS 2417F, Type II, chromate seal, 3-5 mil (AMZ)
 - **Magni 565™** - Chrome-free coating system combining an inorganic zinc-rich basecoat with an aluminum-rich organic topcoat. (Magni)
 - **Alumazite™ ZM 40** – Heat cured, corrosion inhibiting coating w/ no chromate pigments for carbon steel. (Tiodize)
 - **Bare**

Coatings (cont.)

- **SS470**
 - **Cadmium**
 - **Alumazite™ ZY 138** – Heat cured, inhibiting coating with no chromate pigments designed for stainless steels and titanium. (Tiodize)
 - **Bare**
- **Ti-6Al-4V**
 - **Titanium Anodize** – AMS 2488, Type II (Titanium Finishing Co.)
 - **Bare**

Test Method

- **Panel Preparation**

- AA2519-T87: 3"x6"x0.5" and 3"x8"x0.5"
- Clean – Aerowash
- Deoxidize – Ridoline™ 4450
- Pretreat – TCP

- **Prime**

- MIL-DTL-53022 (*Sherwin Williams*)
- MIL-PRF-23377, Class C2, Type I (*Hentzen*)

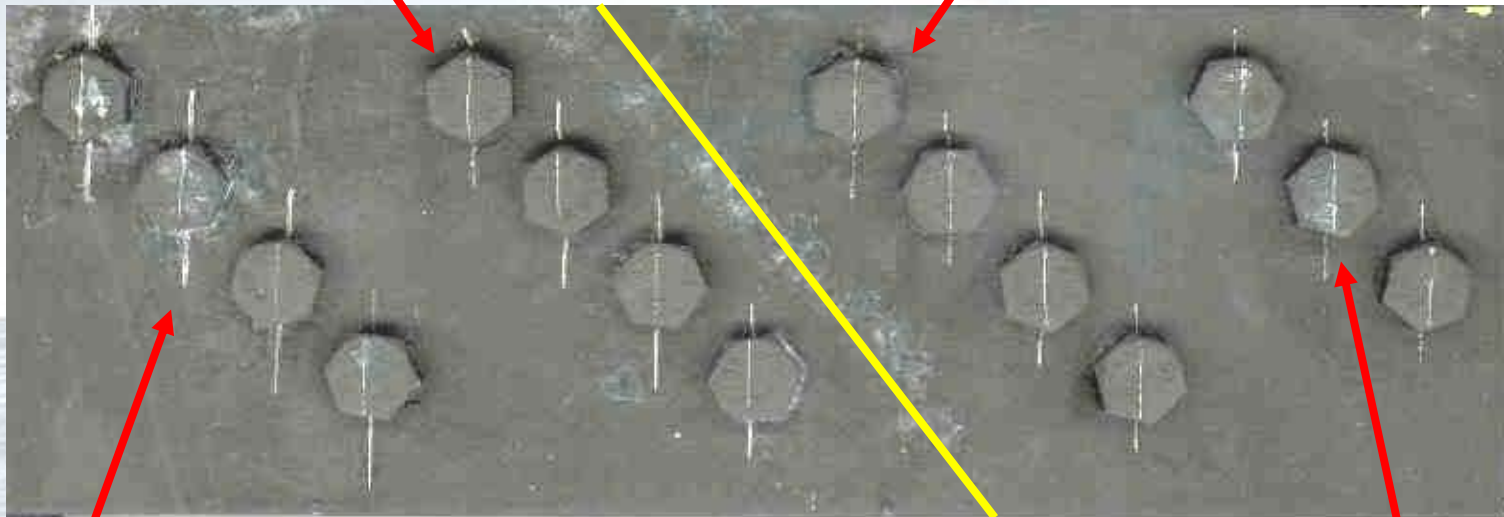
Test Method (cont.)

- **Install Fasteners (55 in. lbs)**
 - 1/4" x 1" hex head bolts
 - S4340
 - SS470
 - Ti-6Al-4V
- **Sealant Application**
 - MIL-PRF-81733D, Type II
 - PR 1775 (PS 1775)
 - Wet Install (53022 or 23377)
 - None (Loctite 242® Threadlocker)
- **Topcoat (Scribed)**
 - MIL-DTL-64159, Type II
- **GM9540P**
 - 80 cycles

Painted Corrosion Evaluation

**S4340 Cd
53022**

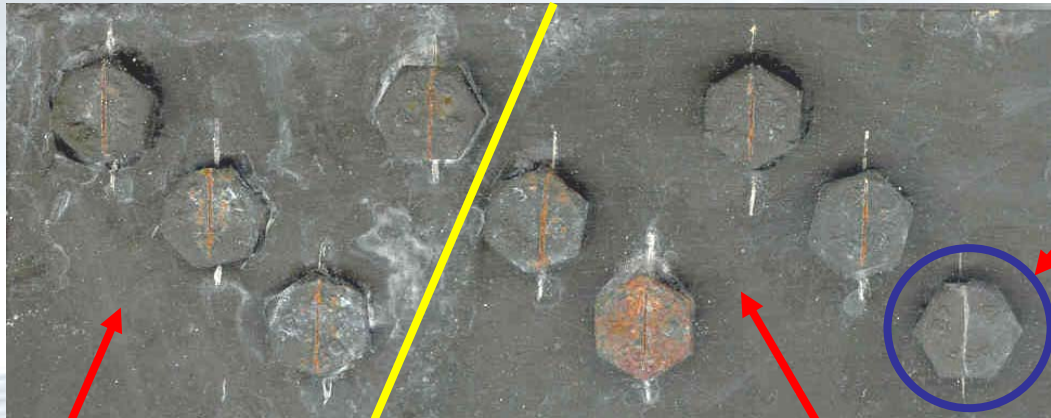
**S4340 Cd
23377**



**S4340 ZnNi
53022**

**S4340 ZnNi
23377**

Painted Corrosion Evaluation (cont.)

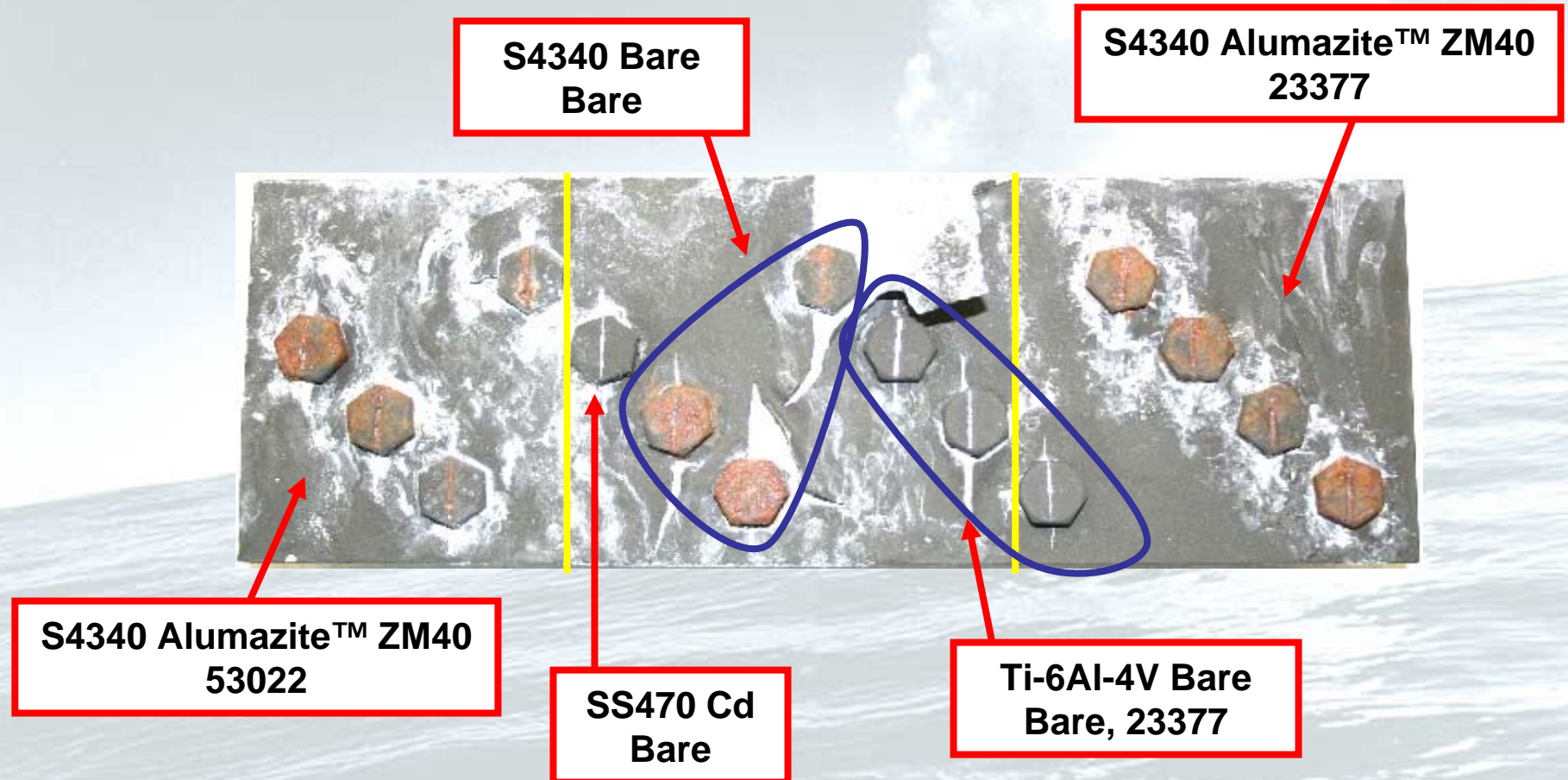


**S4340 Magni 565™
53022**

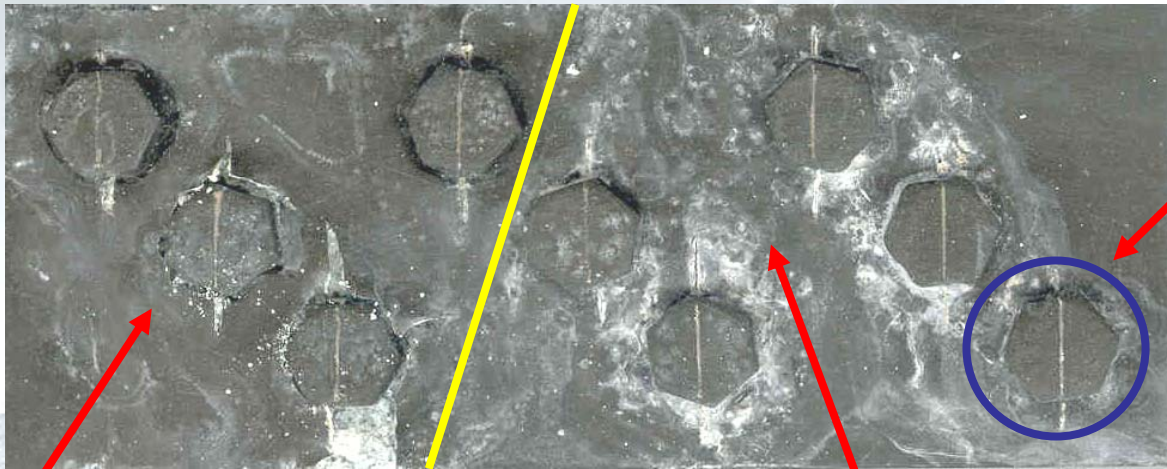
**S4340 ZnNi
23377**

**S4340 Magni 565™
23377**

Painted Corrosion Evaluation (cont.)



Painted Corrosion Evaluation (cont.)



**SS470 Cd
23377**

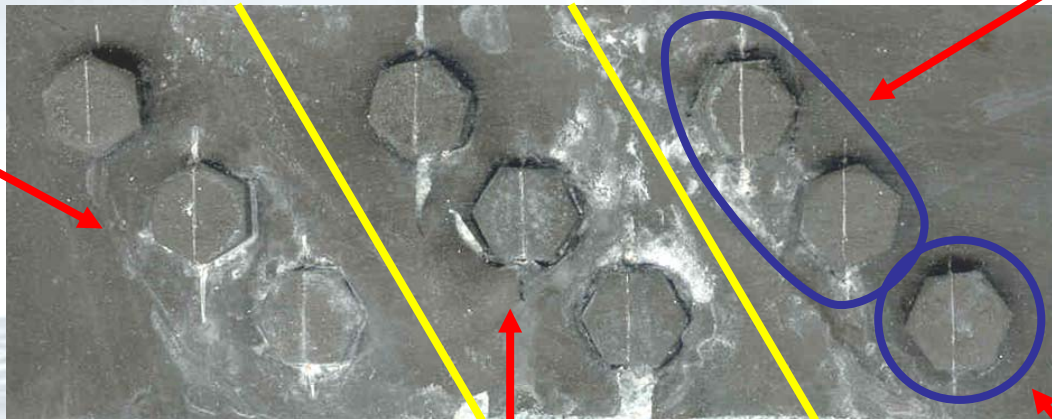
**SS470 Alumazite™ ZY138
53022**

**SS470 Alumazite™ ZY138
23377**

Painted Corrosion Evaluation (cont.)

**SS470 Cd
53022**

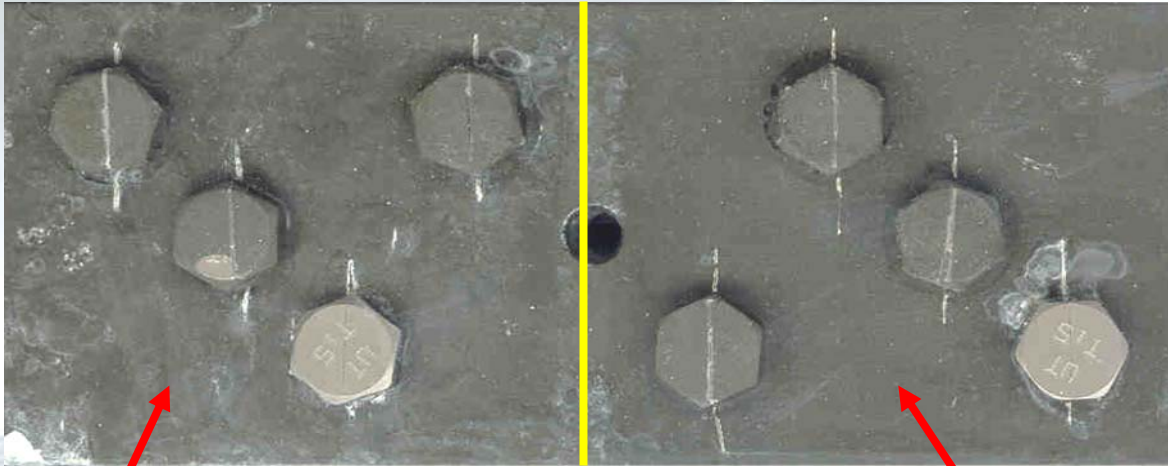
**SS470 Cd
23377**



**SS470 Bare
Bare**

**S4340 ZnNi
23377**

Painted Corrosion Evaluation (cont.)



**Ti-6Al-4V Anodize
53022**

**Ti-6Al-4V Anodize
23377**

S4340 Wet Install

<u>Coating</u>	<u>Primer</u>	<u>Wet Install</u>
ZnNi	23377	23377
Cd		
ZnNi	53022	53022
Cd		
Magni 565™	23377	23377
	53022	53022
Alumazite™ ZM40	23377	23377
	53022	53022
Bare	Bare	53022

SS470 Wet Install

<u>Coating</u>	<u>Primer</u>	<u>Sealant</u>
Cd	23377	23377
	53022	53022
Alumazite™ ZY138	23377	23377
	53022	53022
Bare	Bare	53022

Ti-6Al-4V Wet Install

<u>Coating</u>	<u>Primer</u>	<u>Wet Install</u>
Titanium Anodize	23377	23377
Titanium Anodize	53022	53022
Bare	53022	53022

Overall Wet Install

<u>Fastener</u>	<u>Coating</u>	<u>Primer</u>	<u>Wet Install</u>
S4340	ZnNi	23377	23377
	Cd		
SS470	Cd		
Ti-6Al-4V	Anodize	53022	53022
S4340	ZnNi		
	Cd		
SS470	Cd		
Ti-6Al-4V	Anodize	53022	53022
S4340	Magni 565™	23377	23377
SS470	Alumazite™ ZY 138	23377	23377
SS470	Alumazite™ ZY 138	53022	53022
S4340	Magni 565™	53022	53022

Overall Wet Install (cont.)

<u>Fastener</u>	<u>Coating</u>	<u>Primer</u>	<u>Wet Install</u>
S4340	Alumazite™ ZM 40	23377	23377
S4340	Alumazite™ ZM 40	53022	53022
Ti-6Al-4V	Bare	Bare	53022
SS470	Bare	Bare	53022
S4340	Bare	Bare	53022

Overall 81733D

<u>Fastener</u>	<u>Coating</u>	<u>Primer</u>
S4340	ZnNi	53022
	Cd	53022
		23377
	ZnNi	23377
SS470	Cd	23377
Ti-6Al-4V	Anodize	23377
SS470	Alumazite™ ZY138	23377
		53022
S4340	Magni 565™	23377
		53022
Ti-6Al-4V	Anodize	53022
SS470	Cd	Bare
S4340	Alumazite™ ZM 40	23377
		53022

Overall PR1775

<u>Fastener</u>	<u>Coating</u>	<u>Primer</u>
SS470	Cd	53022
S4340	ZnNi	23377
	Cd	23377
Ti-6Al-4V	Anodize	23377
SS470	Cd	23377
S4340	Cd	53022
SS470	Alumazite™ ZY 138	23377
S4340	Magni 565™	53022
S4340	ZnNi	53022
S4340	Magni 565™	23377
Ti-6Al-4V	Anodize	53022
SS470	Alumazite™ ZY 138	53022

<u>Fastener</u>	<u>Coating</u>	<u>Primer</u>
S4340	Alumazite™ ZM 40	23377
S4340	Alumazite™ ZM 40	53022
Ti-6Al-4V	Bare	Bare
SS470	Bare	Bare
S4340	Bare	Bare

Overall No Sealant

<u>Fastener</u>	<u>Coating</u>	<u>Primer</u>
S4340	Cd	23377
	ZnNi	53022
		23377
	Cd	53022
Ti-6Al-4V	Anodize	23377
S4340	Magni 565™	53022
SS470	Alumazite™ ZY 138	23377
		53022
Ti-6Al-4V	Anodize	53022
S4340	Magni 565™	23377

<u>Fastener</u>	<u>Coating</u>	<u>Primer</u>
Ti-6Al-4V	Bare	23377
S4340	Alumazite™ ZM 40	23377
		53022
SS470	Bare	Bare
S4340	Bare	Bare

Overall S4340

<u>Coating</u>	<u>Primer</u>	<u>Sealant</u>
ZnNi	23377	PR1775
		23377
	53022	81733D
Cd	23377	PR1775
		23377
		None
	53022	81733D
	23377	
ZnNi	23377	81733D
	53022	None
		53022
Cd	53022	PR1775
ZnNi	23377	None
Cd	53022	53022
		None

Overall S4340 (cont.)

<u>Coating</u>	<u>Primer</u>	<u>Sealant</u>
Magni 565™	53022	PR1775
ZnNi		
Magni 565™	23377	81733D
	53022	81733D
	23377	PR1775
		23377
	53022	None
		53022
	23377	None

Overall S4340 (cont.)

<u>Coating</u>	<u>Primer</u>	<u>Sealant</u>
Alumazite™ ZM40	23377	81733D
	53022	
	23377	PR1775
	53022	
	23377	53022
	53022	23377
	23377	None
	53022	
Bare	Bare	53022
		PR1775
		None

S4340 Fasteners

**Cd
53022**

**Cd
23377**



**ZnNi
53022**

**ZnNi
23377**

S4340 Fasteners (cont.)



**Magni 565™
53022**

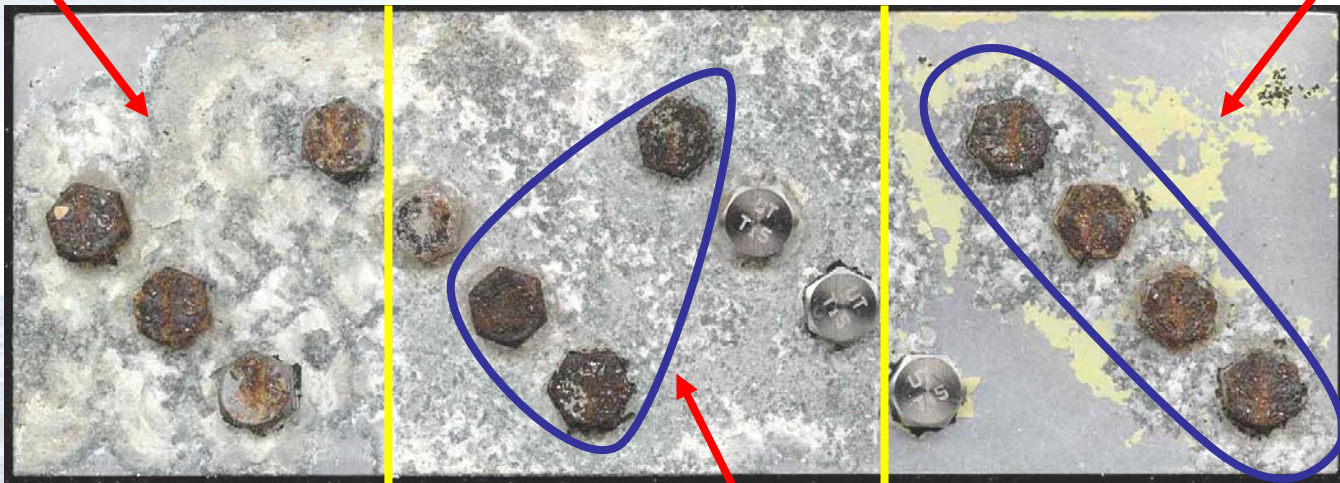
**ZnNi
23377**

**Magni 565™
23377**

S4340 Fasteners (cont.)

**Alumazite™ ZM40
53022**

**Alumazite™ ZM40
23377**



**Bare
Bare**

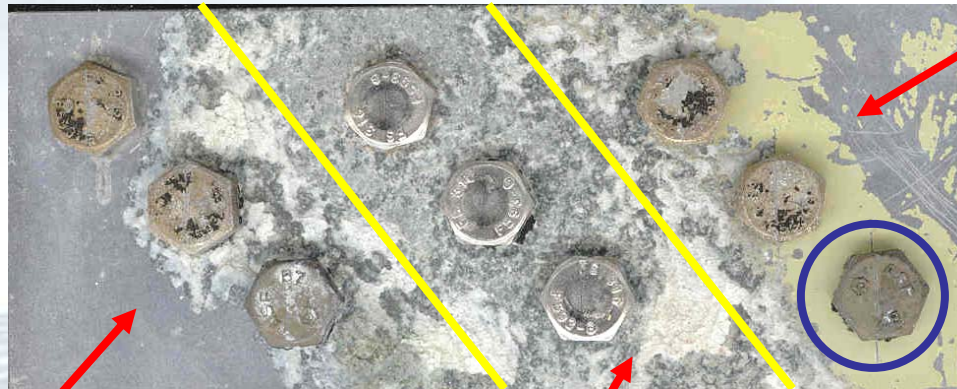
Overall SS470

<u>Coating</u>	<u>Primer</u>	<u>Sealant</u>
Cd	53022	PR1775
	23377	23377
	53022	53022
	23377	PR1775
	23377	81733D

Overall SS470 (cont.)

<u>Coating</u>	<u>Primer</u>	<u>Sealant</u>
Alumazite™ ZY138	23377	81733D
	53022	
	23377	PR1775
	53022	53022
	23377	23377
	23377	None
	53022	
Cadmium	Bare	81733D
Alumazite™ ZY138	53022	PR1775
Bare	Bare	PR1775
		53022
		None

SS470 Fasteners



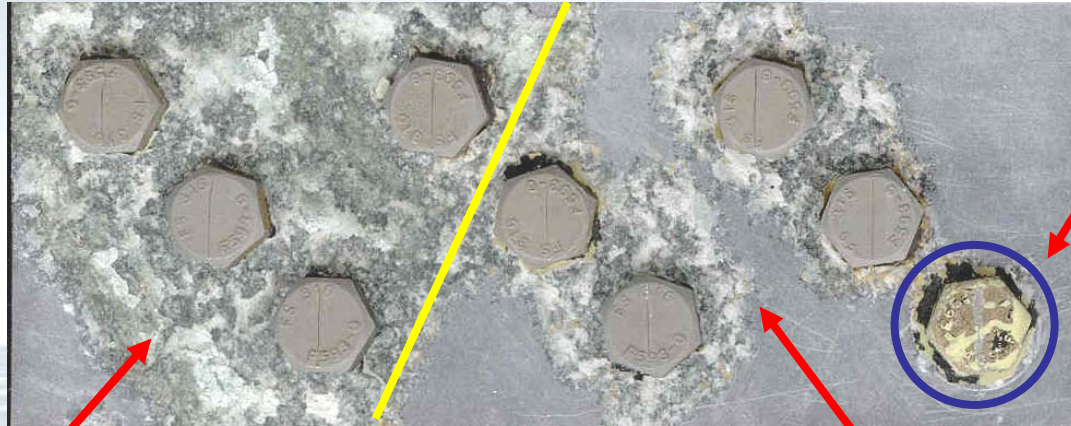
**Cd
53022**

**Cd
23377**

**Bare
Bare**

**ZnNi
23377**

SS470 Fasteners (cont.)



**Alumazite™ ZY138
53022**

**Alumazite™ ZY138
23377**

**Cd
23377**

Overall Ti-6Al-4V

Coating	Primer	Sealant
Titanium Anodize	23377	23377
		PR1775
		None
		81733D
Titanium Anodize	53022	53022
		PR1775
		81733D
		None
Bare	23377	None
	Bare	53022
	Bare	PR1775

Ti-6Al-4V Fasteners



**Anodize
53022**

**Anodize
23377**

Ti-6Al-4V Fasteners (cont.)



**Bare
Bare**

Conclusions

- **S4340**
 - Cadmium and Zinc Nickel ranked at the top.
 - Magni 565™ ranked in the mid-level.
 - Alumazite™ ZM 40 and Bare were clearly at the bottom.
- **SS470**
 - Cadmium was a definite first.
 - Alumazite™ ZY138 is a better alternative than bare but not close to Cadmium.
- **Ti-6Al-4V**
 - Titanium anodize is a much better option than bare.

Recommendations

- **S4340** – Zinc Nickel is the best option as cadmium alternative. Further evaluation recommended.
- **SS470** – Alumazite™ ZY138 is a better option than the current set-up using bare fasteners.
- **Ti-6Al-4V** – Titanium anodize is a better option than the current set-up using bare fasteners.

Additional Information

Additional Information

- AA2519-T87 – High-copper, aluminum armor alloy (sig. weight reduction vs. 5083)
- S4340 – Ni-Cr-Mo high-strength steel
- SS470 – Work-hardened 316 stainless steel alloy
- Ti-6Al-4V – Titanium alloy, 6% aluminum and 4% vanadium.

Additional Information

- Aerowash – Mildly alkaline, all-purpose maintenance cleaner (Henkel)
- Ridoline™ 4450 – Phosphate-free, dilute citric/acetic acid deoxidizer (Henkel)
- TCP – Trivalent chromium conversion coating for aluminum and its alloys (NAVAIR)

Additional Information

- MIL-DTL-53022 – Solvent-borne, non-chromated epoxy primer (Sherwin Williams)
- MIL-PRF-23377, Class C2, Type I – High-solids, solvent-borne, chromated epoxy primer (Hentzen)
- MIL-DTL-64159, Type II – Water-reducible, CARC topcoat (Hentzen)

Additional Information

- MIL-PRF-81733D, Type II – Two-component, room temp curable, polysulfide sealant with a hexavalent chrome inhibitor to prevent corrosion.
- PR 1775 – Two-component room temp curable, polysulfide sealant with a non-chromate inhibitor to prevent corrosion.

Additional Information

- GM9540P – Accelerated, cyclic corrosion test. Three stages repeated for each cycle:
 - 8 hr ambient with 4 salt mist applications every 90 min (40%-50% RH, 25C)
 - 8 hr humidity (100% RH, 49C)
 - 8 hr dry (<30% RH, 60C)

Additional Information

- Zinc Nickel – Plating performed in accordance with AMS 2417F Type II at a thickness of 0.0003" - 0.0005" - post-treated with hexavalent chrome (AMZ)
- Cadmium – Plating performed in accordance with ASTM F519, Table II, Treatment B, chromate seal, 0.5 mil (NAVAIR)
- Magni 565™ – Chrome-free duplex fastener coating system that combines an inorganic zinc-rich basecoat with an aluminum-rich organic topcoat.

Additional Information

- Alumazite™ ZM40 – Heat cured, corrosion inhibiting coating with no chromate pigments for carbon steel (Tiodize)
- Alumazite™ ZY138 – Heat cured inhibiting coating with no chromate pigments designed for stainless steels and titanium(Tiodize)
- Titanium Anodize – Anodized in accordance with AMS 2488, Type II (Titanium Finishing Company)

S4340 Fasteners

Cd
53022

Cd
23377



ZnNi
53022

ZnNi
23377

S4340 Fasteners



ZnNi
23377

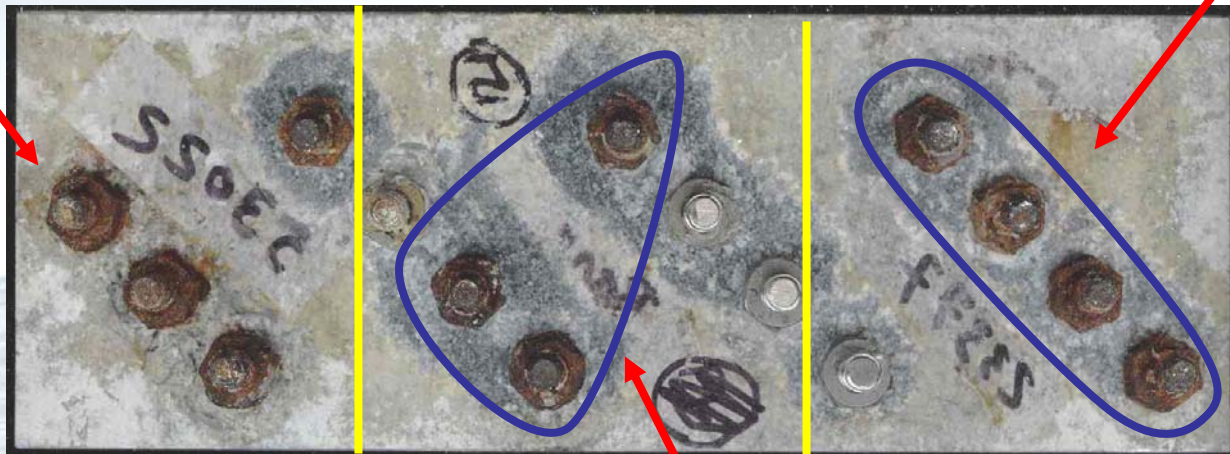
Magni 565™
53022

Magni 565™
23377

S4340 Fasteners

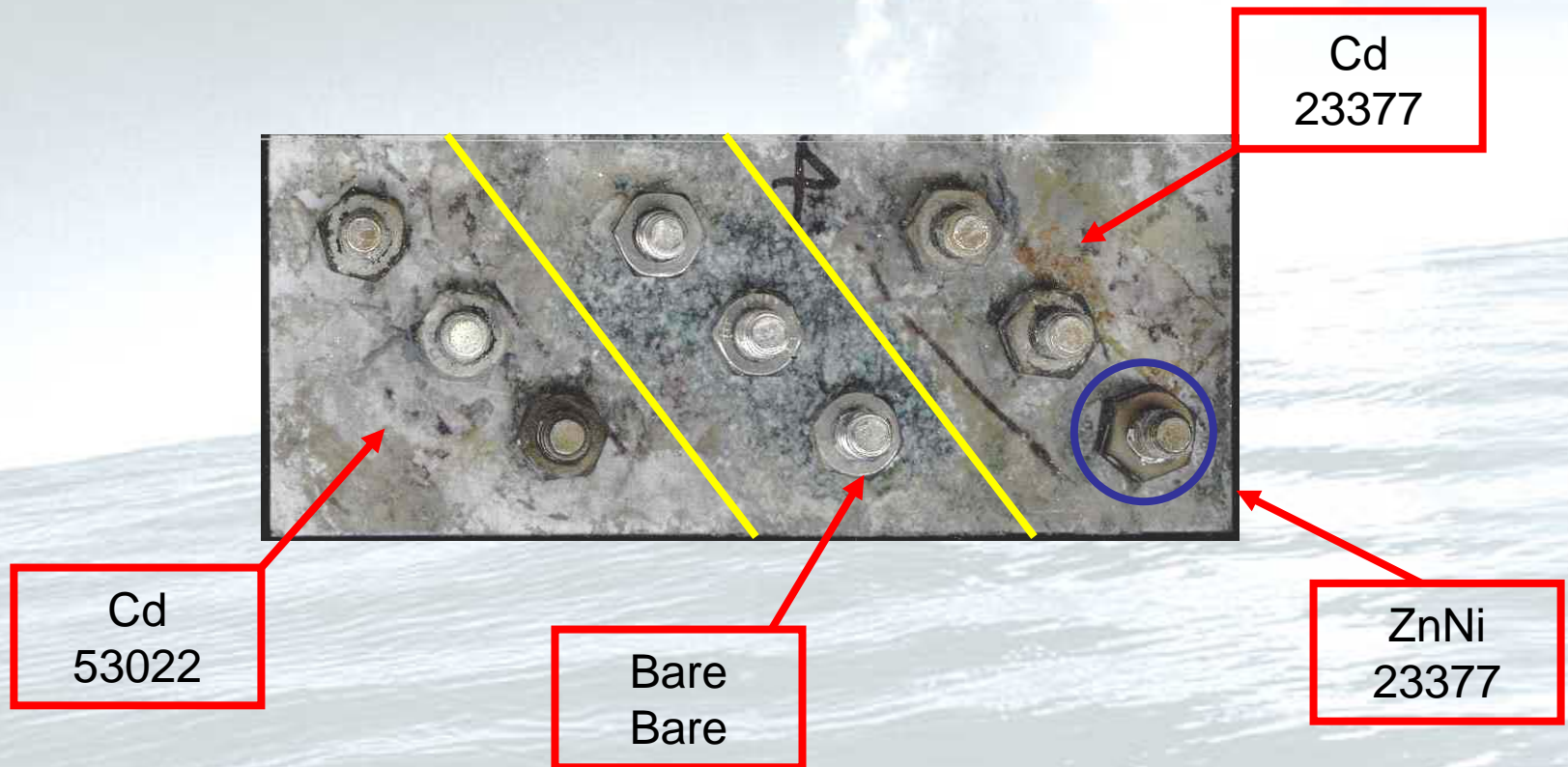
Alumazite™ ZM40
53022

Alumazite™ ZM40
23377

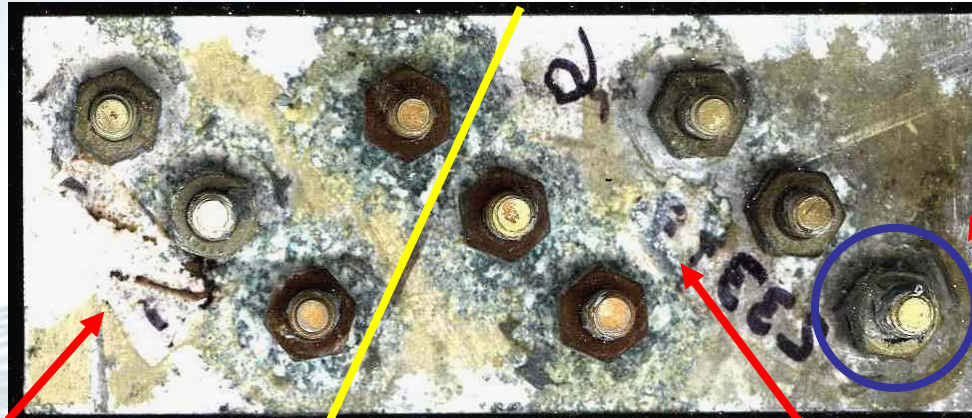


Bare
Bare

SS470 Fasteners



SS470 Fasteners



Cd
23377

Alumazite™ ZY138
53022

Alumazite™ ZY138
23377

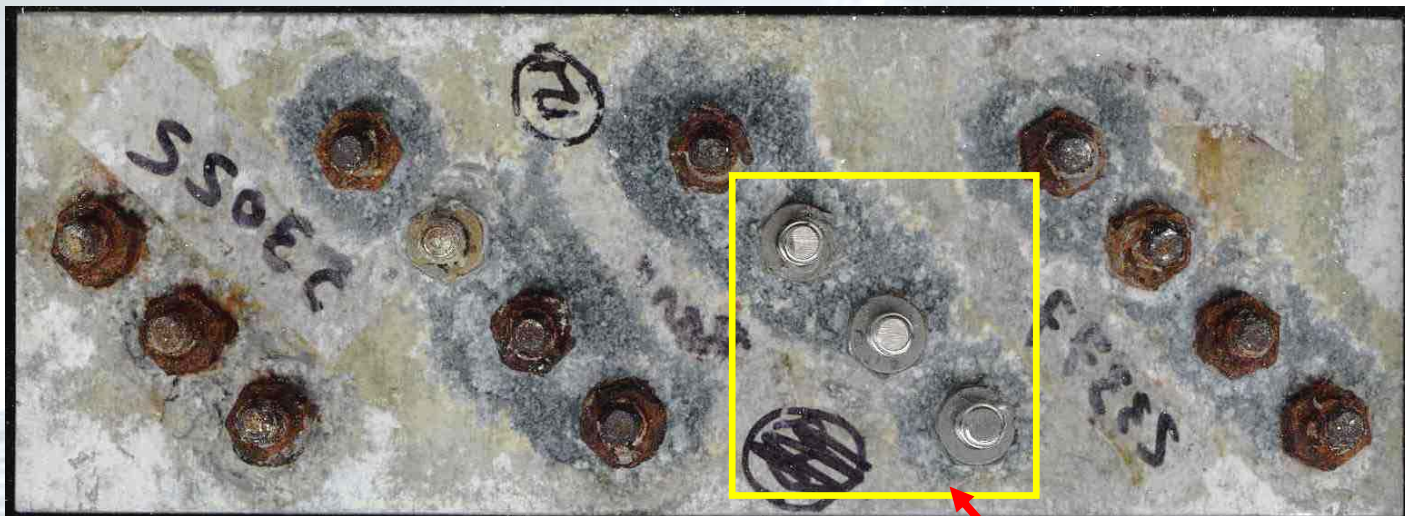
Ti-6Al-4V Fasteners



Anodize
53022

Anodize
23377

Ti-6Al-4V Fasteners



Bare
Bare